



Survey Of The Fermilab D0 Detector Collision Hall

*Babatunde O'Sheg Oshinowo, Ph.D, FRICS
Alignment and Metrology
Fermi National Accelerator Laboratory
Batavia, IL 60510*

ABSTRACT

The Fermilab D0 detector was used for the discovery of the top quark during Run I in 1996. It had been upgraded to exploit the physics potential to be presented by the Main Injector and the Tevatron Collider during Run II. The upgrade of the D0 detector was fully commissioned on March 1, 2001, and thus marked the official start of the Run II experiment. The detector which weighs about 5500 tons, was assembled in the Assembly Hall. Prior to moving the detector into the Collision Hall, the existing survey monuments were densified in the Collision Hall with new monuments. This paper discusses the survey of the Collision Hall using a combination of the Laser Tracker, BETS, V-Stars, and other Optical systems to within the specified accuracy of $\pm 0.5\text{mm}$.

1. INTRODUCTION

The D0 experiment at the Fermilab Tevatron proton-antiproton collider is a general purpose collider detector experiment, built to study proton-antiproton collisions at the center-of-mass energy of 1.8 TeV. It is one of two collider detectors at Fermilab (Figure 1). Following the successful operation of the D0 detector during Run I, it received substantial upgrade modifications in preparation for Run II. The upgrades were made to the detector while it was in the D0 assembly hall. Immediately prior to the beginning of Run II it was rolled into the D0 collision hall ("roll-in") where the proton-antiproton collisions take place.

1.1 The Fermilab D0 Detector

The D0 detector consists of several unique detector subsystems each specifically provided to measure the properties of one or more classes of elementary particles. Among the subsystems are the Liquid Argon Calorimeters, the Solenoid Magnet, the Central Fiber Tracker, the Preshower Detectors, the Muon System, etc. The D0 detector is designed in layers like a



"Russian Doll", the innermost detectors are covered by successive layers of detectors. An overall view of the D0 detector is shown in Figure 2 with the primary detector subsystems indicated.

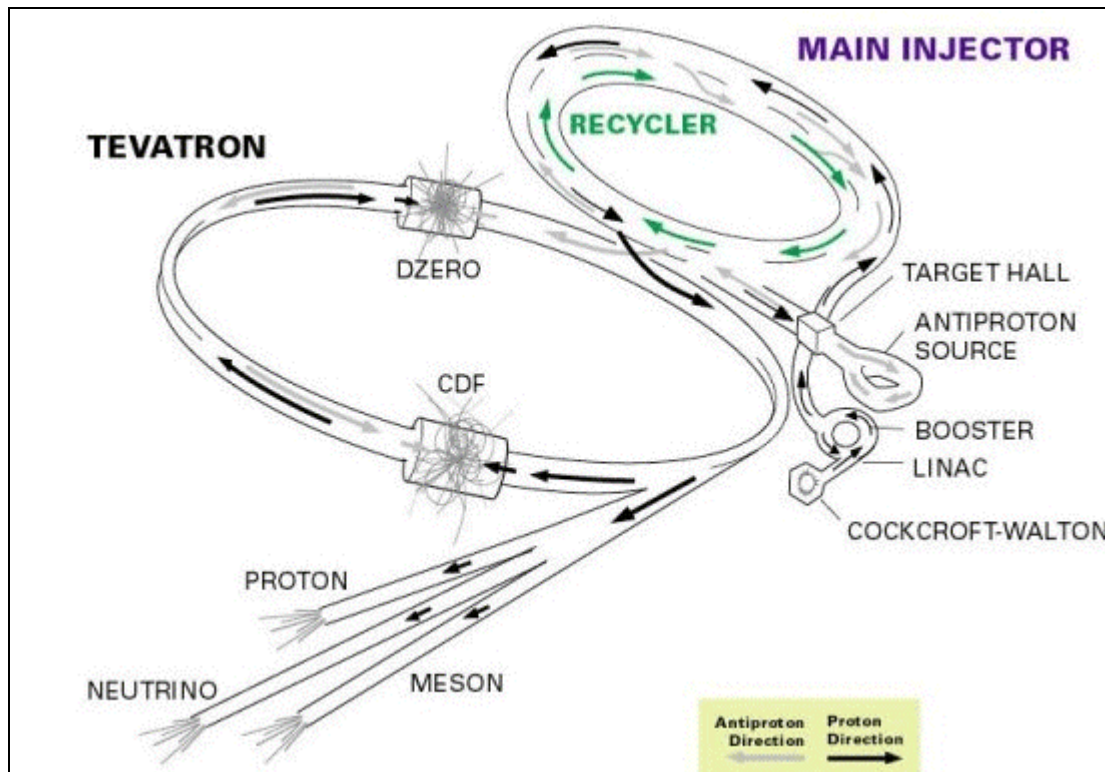


Figure 1. Fermilab's Accelerator Chain

One of the salient components of the D0 detector is a highly stable, liquid argon calorimeter. It consists of three units, the Central Calorimeter (CC), and the two End-cap Calorimeters (EC). The calorimeter system provided excellent energy resolution of both pions and hadrons during Run I and is retained for Run II. A major new component of the upgraded detector is a 2 Tesla superconducting solenoid magnet newly fabricated for Run II. It is the first thin solenoid for a particle physics detector which operates at 2 Tesla. Another important element of the upgraded detector is the new Run II Central Preshower Detector. It consists of scintillating fibers mounted on eight concentric cylinders, all superimposed on a thin lead radiator. After the Central Preshower Detector was installed on the outer diameter of the solenoid cryostat, the magnet and preshower detector were installed into the center bore of the existing Central Calorimeter cryostat. The Forward Preshower detector, also new for Run II, is located in front of each End-cap Calorimeter (EC). It consists of a lead radiator and four scintillator layers numbered from 1 to 4, starting with the layer closest to the interaction point.

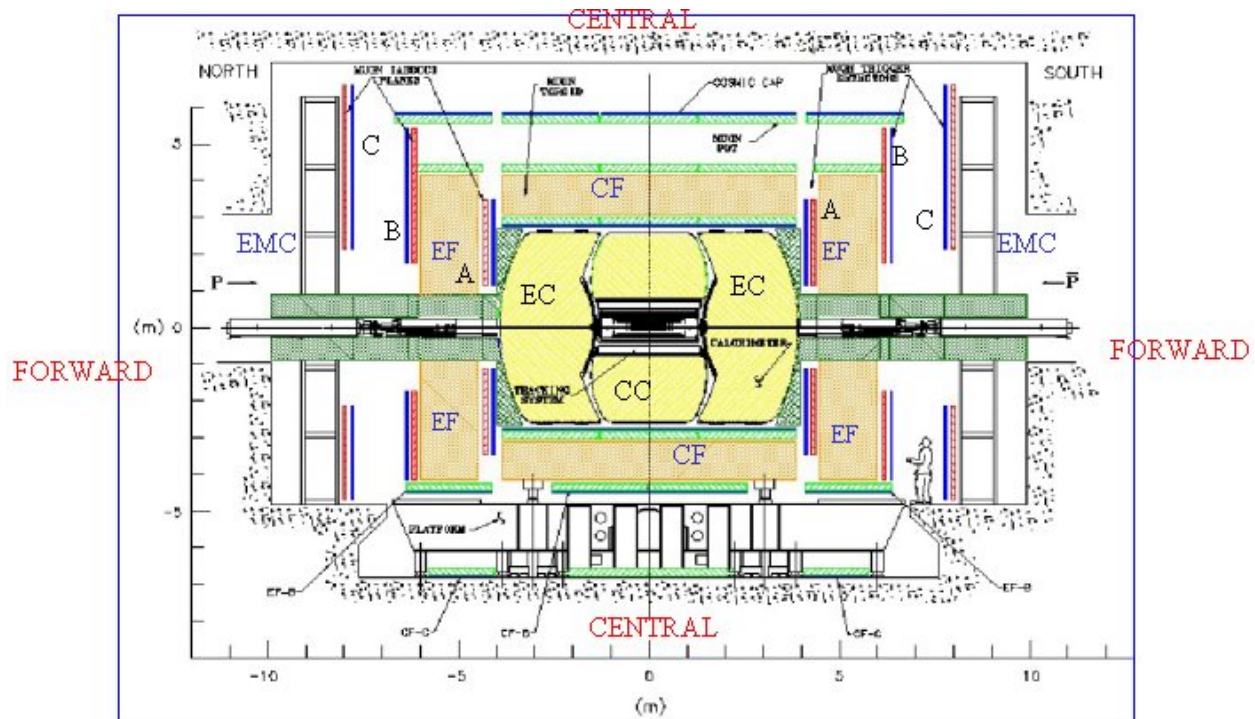


Figure 2. Side view of the D0 upgrade detector

The upgraded muon system for Run II has three active layers. The three layers are designated A, B, and C, where the A-layer is closest to the interaction region and a toroid magnet (consisting of a thick layer of magnetized steel) is located between the A and B layers. Contained in the A and B layers are the three basic subsystems of the upgraded muon system – the Proportional Drift Tube (PDT) chambers, the Mini-Drift Tubes (MDTs) and the Pixel Counters. The muon system is geographically divided into two detectors: the central muon detector and the forward muon detector.

The central muon detector consists of a toroid magnet, large PDT drift chambers, the C-layer counters, the CF Bottom B- and C-layer counters, the EF Bottom B-layer counters, and the A-layer scintillation counters. The central toroid magnet (sometimes referred to as the CF steel), Figure 2, is a square annulus 109 cm thick weighing 1973 metric tons. It is built in three sections in order to allow access to the inner parts of the detector. The center-bottom section is a 150 cm wide beam, fixed to the detector platform, providing a base for the calorimeters and tracking chambers. It is called the centerbeam (CB). To complete the CF toroid, there are two C-shaped sections (east and west CF toroid), which can be moved horizontally, perpendicular to the centerbeam, to gain access to the detectors within.



The forward muon detector consists of a toroid magnet, three layers of Mini-Drift Tubes (MDTs) for muon track reconstruction, and three layers of Pixel Counters for triggering on events with muons. The forward (EF) toroid magnet between the A and B layers is 160 cm thick. The forward muon detector is geographically divided into two identical sections, the North and South sections of the detector. Both can be moved horizontally, parallel to the centerbeam, to gain access to the detector systems within.

The EMC (End Muon Chamber) Truss is a 40 foot high metal structure that is used to hold the forward B- and C-layer MDT and Pixel planes. The north and south EMC trusses are located on the sidewalks next to the north and south walls of the collision hall.

1.2 Survey of the D0 Detectors

The layered "Russian Doll" design of the D0 detector meant that the innermost detectors were covered by successive layers of detectors as D0 was constructed, and were not available for survey measurements after D0 was completely assembled. The survey of the D0 detectors was done in three phases. Phase I was the initial survey and referencing of all the internal features of individual detector components. Phase II was the measurement of the relative locations of the detectors as they were assembled on the detector centerbeam. The individual components were surveyed to points fixed to the exteriors of the detectors. The Phase I and Phase II surveys were done in the assembly hall and were completed in the Fall of 2000 [2]. The required accuracy for both phases was specified as better than 0.5 mm for most of the components.

The Phase III survey was used to determine the position of the components in the collision hall. In order to do the Phase III survey several points must be established and surveyed in the collision hall. The Phase III survey is the final measurement, made in the collision hall and must be repeated with each opening/closing of the D0 detector. The survey method to be used depends on the accessibility and space constraints at the time of survey. The required accuracy for the Phase III survey is specified as better than 0.5 mm.

The purpose of surveying the collision hall is to be able to do the Phase III measurements. This paper discusses the survey of the Collision Hall using a combination of the Laser Tracker, BETS, V-Stars, and other Optical systems to within the specified accuracy.



Figure 3. D0 Collision Hall

2. THE D0 COLLISION HALL

The Fermilab Tevatron proton-antiproton collisions take place in the collider detector inside the D0 collision hall (Figure 3). The dimensions of the hall are 777.89 inches (64.9 ft) in the north-south direction, 600.0 inches (50.0 ft) in the east-west direction, and 534.0 inches (44.5 ft) from the floor to the ceiling. The hall consists of two sidewalks which are 120 inches (10.0 ft) wide in the north-south direction and 90.0 inches (7.5 ft) above the floor of the hall (Figure 4). The lower section of the hall below the sidewalks is referred to as the “pit” and is 588.89 inches (49.1 ft) in the north-south direction. Figure 5 shows the D0 detector in the collision hall after roll-in. The north, south and west walls are permanent concrete walls of the D0 building and the collision hall. The east wall consists of shielding block wall that separates D0 the collision hall from the D0 assembly hall. The shielding blocks are removed prior to rolling the detector into the collision hall, and are rebuilt after roll-in (Figure 6).

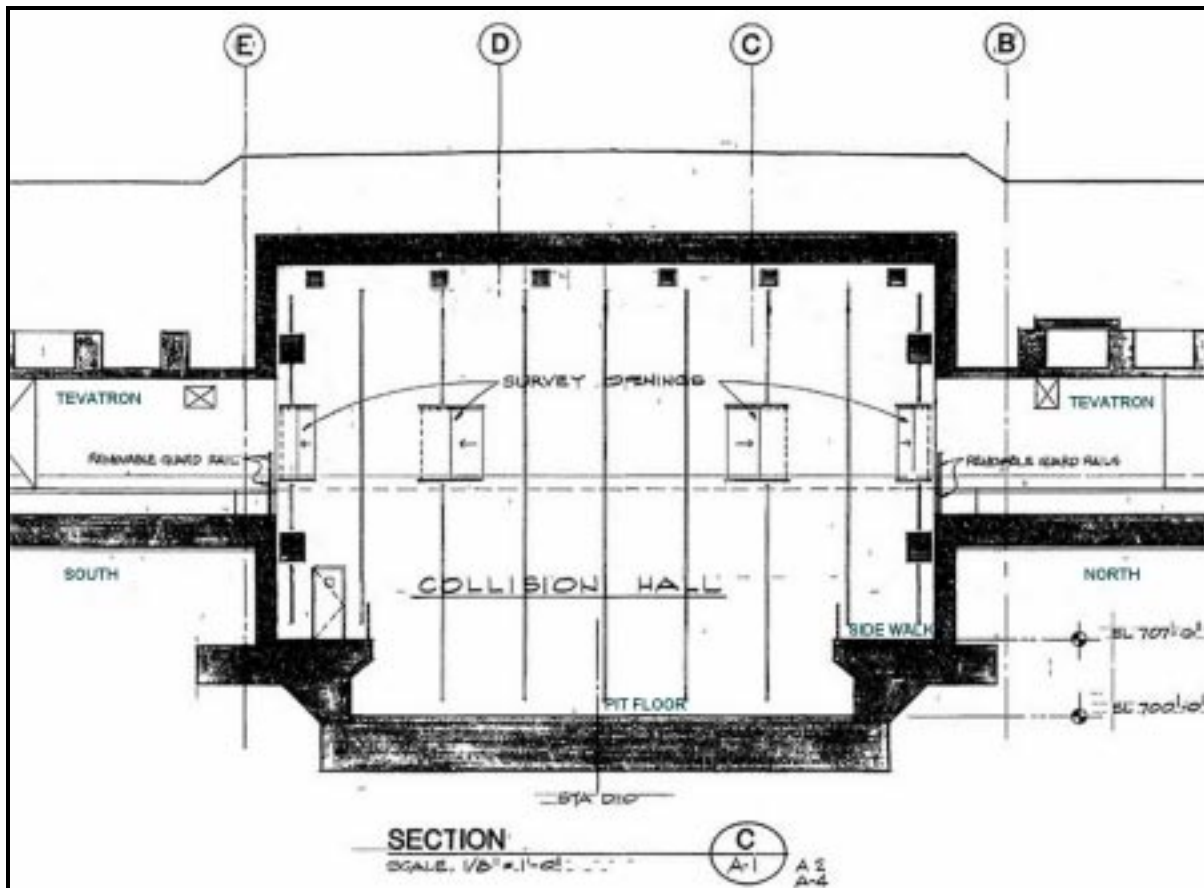


Figure 4. Cross Section of D0 Collision Hall

The north and south end walls of the upper section of the collision hall each contain a 162. in x 162 in. (13.5 ft x 13.5 ft) hole in the center leading into the Tevatron tunnel. The west wall contains several doors (“survey openings” or “rifle slits”) leading into the Tevatron tunnel. All survey ties between the Tevatron and the collision hall are done through this openings (Figure 4).



Figure 5. D0 Detector inside the Collision Hall

3. SURVEY OF THE D0 COLLISION HALL

3.1 D0 Global Coordinate System

The Tevatron based D0 global coordinate system used in the collision hall survey is a right-handed Cartesian coordinate system defined as follows:

- Origin - Tevatron Beam Centerline as defined by the center of the D0 Low Beta Quads at elevation of 8680.414 inches (723.3678 ft) and the Interaction Point of the detector.
- X-axis - EAST axis. Positive to the right and perpendicular to the Y-axis
- Y-axis - NORTH axis. Positive along the anti-proton beam direction
- Z-axis - Positive up and perpendicular to both X- and Y-axes.



Figure 6. Detector inside Collision Hall and the East Shielding Block Wall

3.2 Survey Methods

The SMX Laser Tracker and its associated software are used for establishing control points. The Laser Tracker is a device that makes three-dimensional measurements. It uses a laser distance meter, two precision angle encoders and proprietary software to calculate, store and display the real-time three-dimensional position of a mirrored target positioned on the desired point or feature. The mirrored target is a spherically mounted retroreflector (SMR).

The BETS (Brunson Electronic Triangulation System) is a portable non-contact, three-dimensional coordinate measuring system. The system consists of precision electronic theodolites connected to a computer via cabling and a theodolite interface module. The computer has software that can display real time three-dimensional coordinates and statistical information.

The V-Stars system is a portable non-contact, three-dimensional digital photogrammetric system. The system consists of one or two digital cameras and software. To measure an object,

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the camera(s) are used to photograph the object from various directions. The digital images are processed immediately by the software to provide three-dimensional coordinates and statistical information. The software is based on photogrammetric-bundle- triangulation methods.

Optical (Wild N3) and electronic (Leica NA3000) levels are used for elevations and stick micrometers (“stick-mics”) for distances between very close points. Optical Tooling techniques are sometimes used for making measurements from the detector to the control points.

3.3 Control Points

During Run I, the Tevatron system was defined horizontally by a network of 25 brass points in the collision hall sidewalks and pit floor and vertically by elevations of the low beta quads transferred into the hall and tied to several tie-rods [6]. The network was surveyed in the Fall of 1992 using the BETS system. It also included existing tooling balls and tie-rods on the west wall. The brass point is a flat flushed brass surface with a very small punched hole in the middle (Figure 7a). A floor centering plate is used to set over a brass point (Figure 7b); a pin nest and a target fixture sit on the floor plate.



Figure 7a. Brass Control Point.

Figure 7b. Centering Plate with Nest and SMR over Brass

For the Run II survey, the old 1992 network was densified with 38 new control points in the collision hall sidewalks, the north, south and west walls, and the pit floor (Figures 10 through 15). To avoid using floor centering plates over brass points, a dead bolt (“Dijak bolt”) with a 0.250 inch hole was used for control point (Figure 8a). The dead bolt is a modified $\frac{3}{4}$ x 10 inch

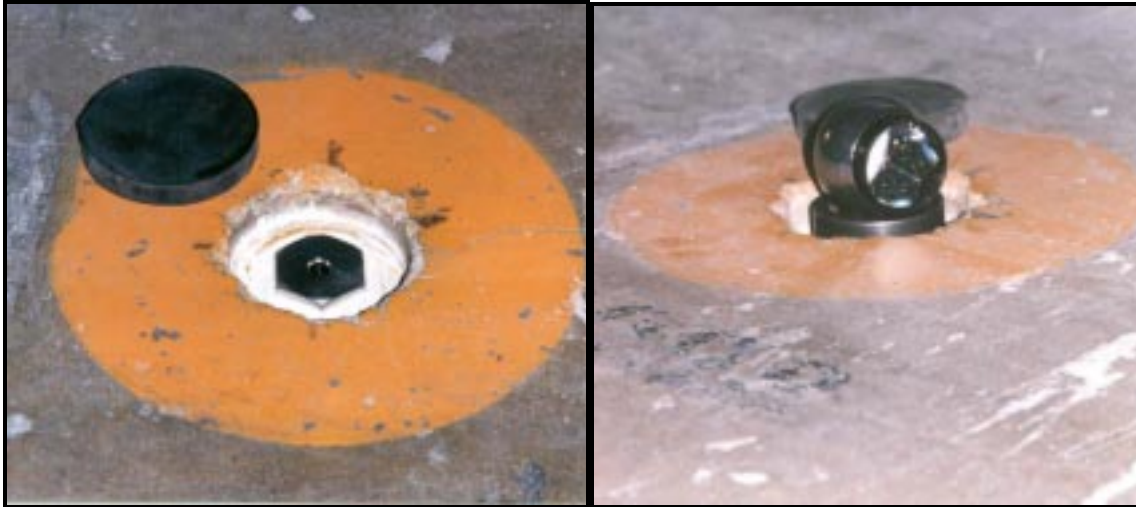


Figure 8a. Exposed Dead Bolt.

Figure 8b. Dead Bolt with Nest and SMR



Figure 9a. Nest, Adapter and SMR on Tie Rod. **Figure 9b.** Stick-Mic Adapter and Nest on Dead Bolt

stainless steel hex head bolt, machined to provide a high accuracy, repeatable point of monumentation. It is used as a sub-surface, corrosion resistant, low cost, horizontal and vertical monument, that is easily installed. The 0.250 inch hole provides a receptacle for Laser Tracker and optical tooling fixtures (Figures 8b and 9b). Figure 9a shows a tie-rod used for elevation monumentation and the fixture used on the tie-rod for measurements.

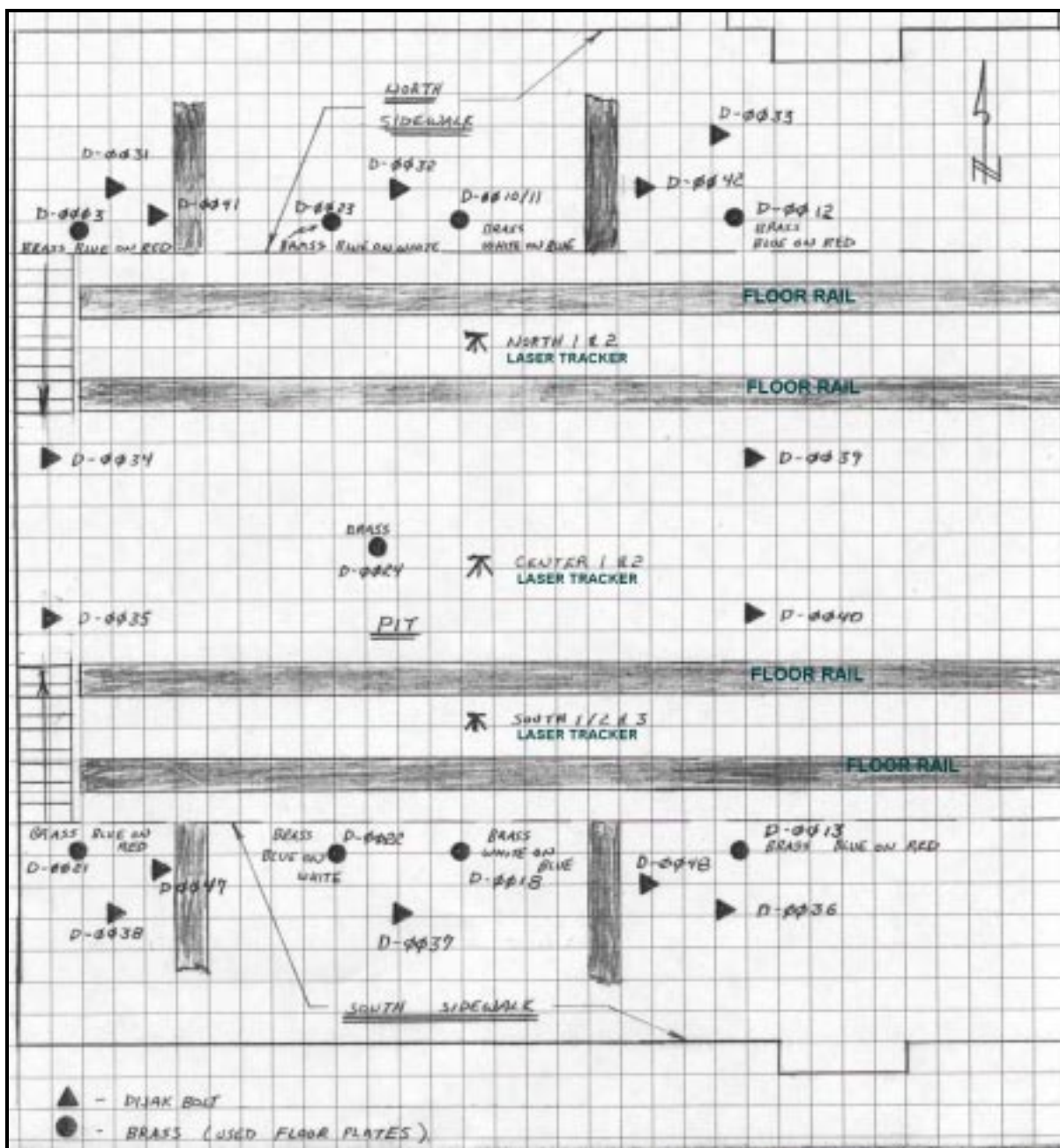


Figure 10. Collision Hall Laser Tracker Network; Plan view

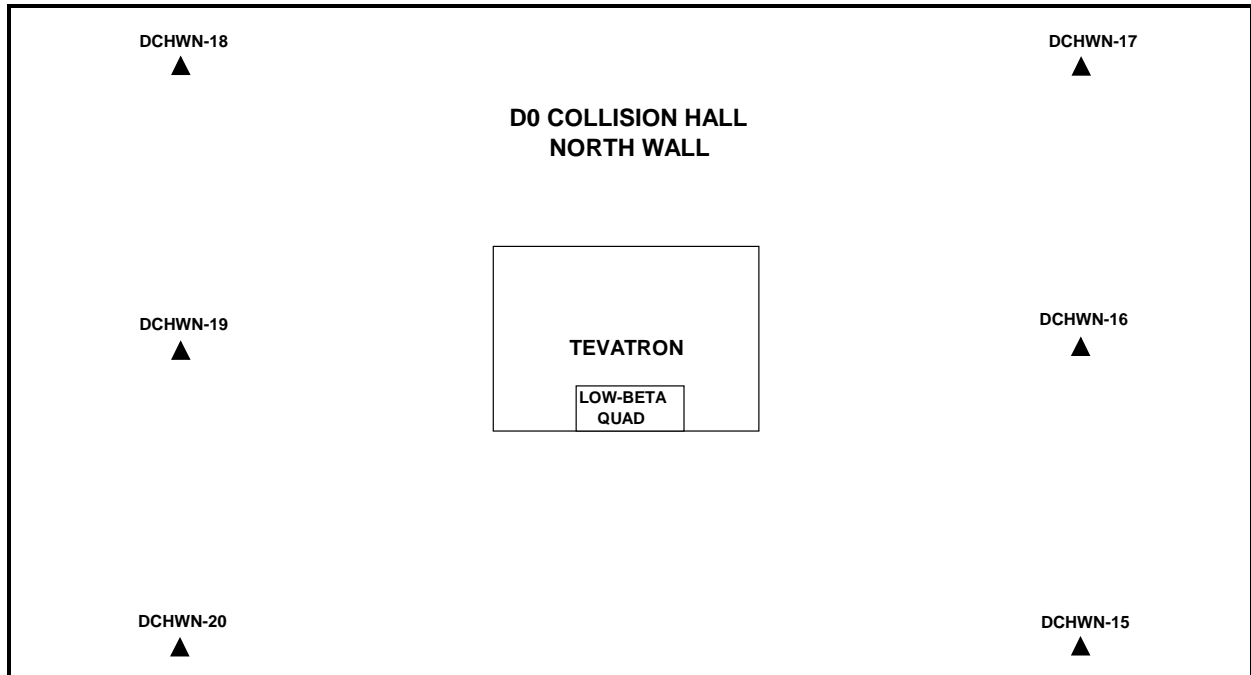


Figure 11. Collision Hall North Wall with Controls

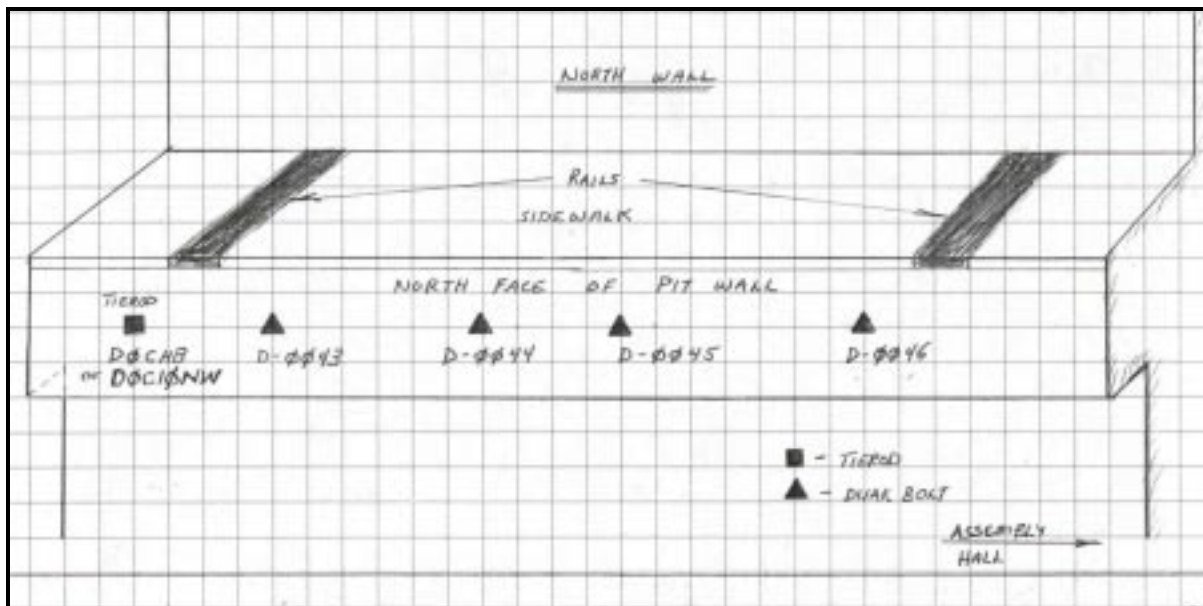


Figure 12. North Face of Pit Wall of Collision Hall with Controls



3.4 Survey Measurements

3.4.1 BETS Measurements

By mid-November 2000, while the collision hall was empty and the east shielding block

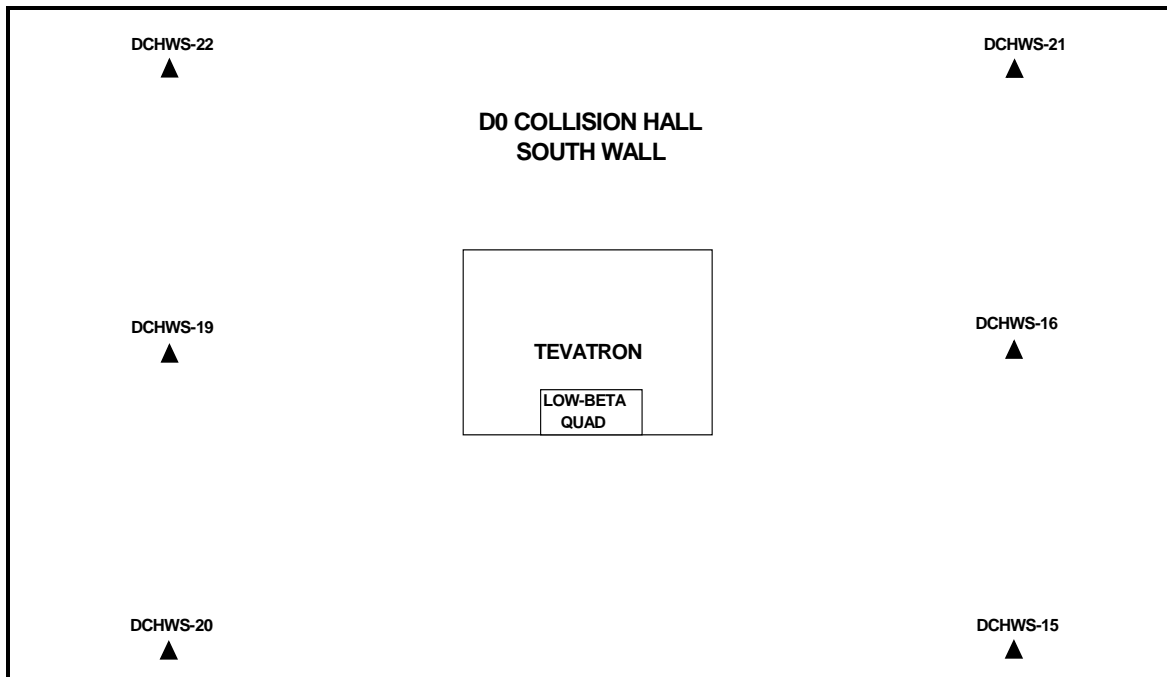


Figure 13. Collision Hall South Wall with Controls

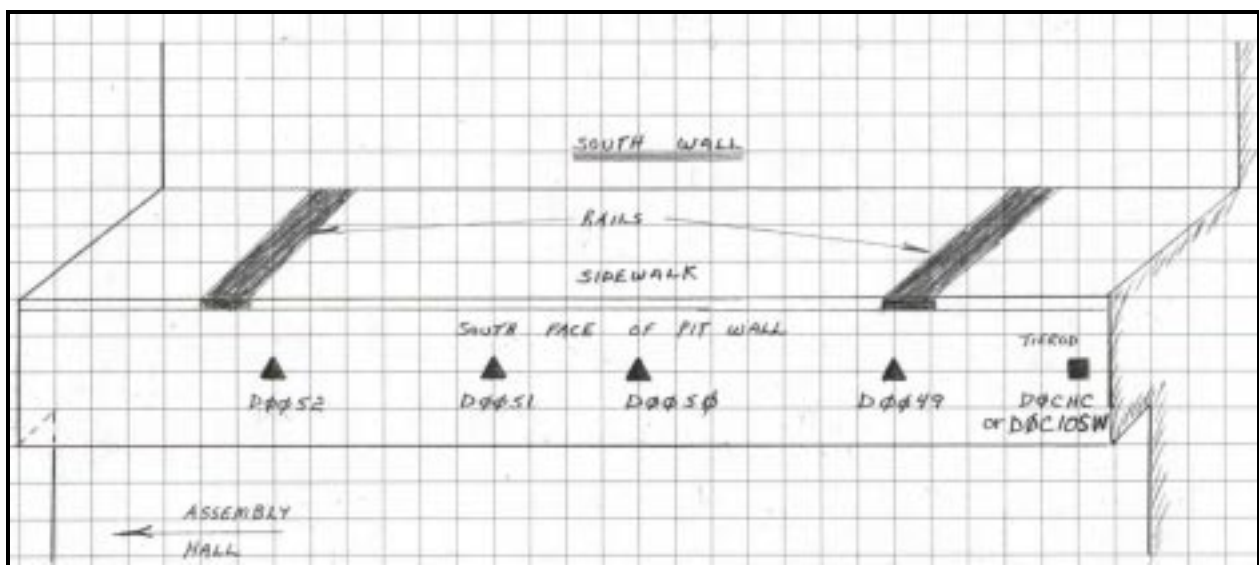


Figure 14. South Face of Pit Wall of Collision Hall with Controls



wall still in place, the control points installed at that time on the north and south wall and the floor points were surveyed. To target some of the high points on the north and south walls a vertical motion only “Genie” lift was used. The highest points desired could not be reached by the lift available at that time. This survey was tied to the D0 global coordinates system by using four old brass control points. The BETS measurements were recorded in rectangular Cartesian coordinates (X, Y, Z).

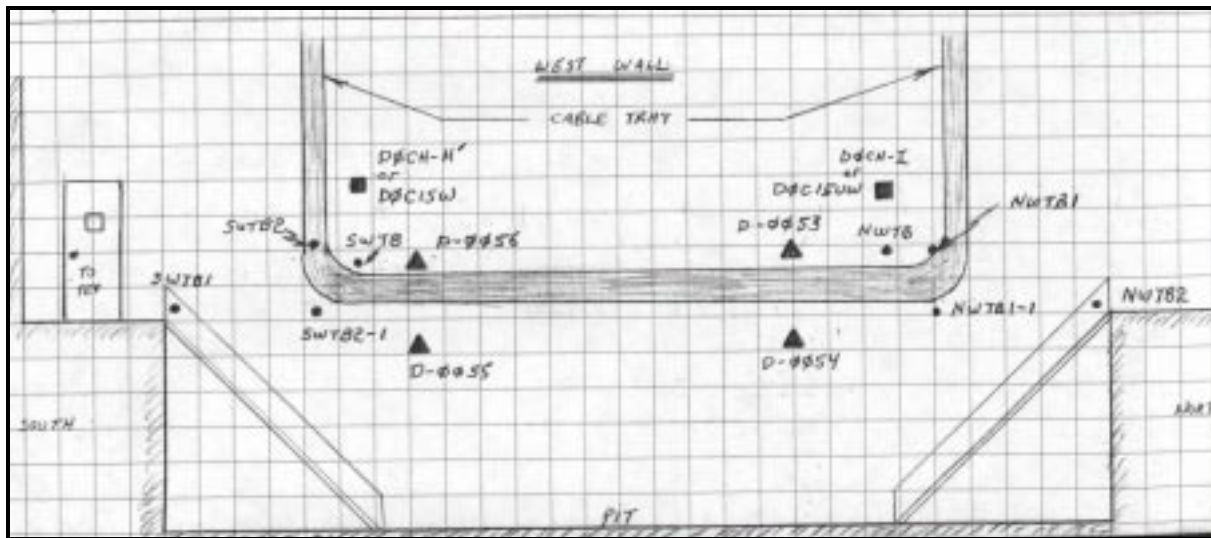


Figure 15. Collision Hall West Wall with Controls

3.4.2 V-Stars Measurements

By the end of November the EMC trusses had been rolled into the collision hall on the north and south sidewalks (Figure 1). As part of the survey of the EMC trusses, the highest points on the north and south walls were installed and surveyed using the V-Stars system. The highest points were targeted using the articulating arm “Blue Genie” lift from the sidewalk. There was no way to get the Genie lifts onto the collision hall floor because of the east shielding block wall. The V-Stars measurements were recorded in rectangular Cartesian coordinates (X, Y, Z).

3.4.3 Laser Tracker Measurements

By the end of January 2001 more control points had been added, the east shielding block wall had been removed, and the north and south wall control points above the side walk had been

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covered by the EMC trusses. Using the Blue Genie lift, a Laser Tracker survey was performed. In order to cover the whole area of the collision hall and to have redundant measurements, there were two Tracker setups on the north side of the pit floor, three setups in the center of the hall, and three setups on the south side of the pit floor (Figure 10). All data sets were combined into the North, Center and South data sets. Since the Laser Tracker is not a gravity-based coordinate system, data was collected in the internal Tracker head coordinate measuring system. Laser tracker measurements were recorded in both rectangular Cartesian coordinate (X, Y, Z) and polar coordinate (r, θ , ϕ) systems, where r is the radial interferometric distance, θ is the horizontal (azimuth) angle, and ϕ is the vertical (elevation) angle. The relationship between the two systems is given by [3][4],

$$\begin{aligned}X &= r \cos \theta \sin \phi \\Y &= r \sin \theta \sin \phi \\Z &= r \cos \phi\end{aligned}$$

The Laser Tracker survey included nine old 1992 brass control points which are used to transform the Tracker measurements into the D0 global coordinates system.

3.4.4 Elevation Measurements

An elevation run was performed starting from station C-49 in the Tevatron tunnel on the north side of the collision hall and elevation was transferred to tie rod D0C15UW on the west wall through the survey opening (Figures 4 and 15). Another elevation run started from station D-11 in the Tevatron tunnel on the south side of the collision hall and elevation was transferred to tie rod D0C15W on the west wall (Figure 15). Finally an elevation run was carried out to two other tie-rods and eight floor control points. The elevations of the four tie-rods and the eight control points were held fixed in the network adjustment. After roll-in, other elevation runs were performed as described above toward the end of February and May 2001.

3.5 Data Processing and Network Adjustment

The final data analysis was completed by numerical optimization which transforms the measured (Laser Tracker, BETS, V-Stars) coordinate system into the D0 global coordinate system. To rotate the measured coordinate system to the D0 global coordinate system, a seven-parameter transformation is performed using the following expression:

$$\underline{\mathbf{X}}_G = \underline{\mathbf{X}}_{\text{Trans}} + \mathbf{S} * \mathbf{R}(\epsilon_X, \epsilon_Y, \epsilon_H) * \underline{\mathbf{X}}_M$$



where $\underline{\mathbf{X}}_G$ is the vector containing the (XYZ) coordinates in the D0 global coordinate system; $\underline{\mathbf{X}}_M$ is the vector containing the measured (XYZ) coordinates; $\underline{\mathbf{X}}_{\text{Trans}}$ is the vector containing the translation parameters in XYZ; $\mathbf{R}(\epsilon_X, \epsilon_Y, \epsilon_H)$ is the rotation matrix; and S is the scale. For this survey the scale is fixed at $S = 1.000000$. The optimum rotation matrix \mathbf{R} and transformation vector \mathbf{X} is obtained by minimizing a chi-square formed between selected measured points in both data sets.

In the transformations for this survey, the gravity based elevations of the tie-rods and new control points were held fixed to their measured values.

3.5.1 Laser Tracker Data Processing

The Laser Tracker measurements (North, Center, South setups) were processed in three different ways:

1. In the Laser Tracker head system, the North and South (X,Y,Z) measurements were respectively transformed to the Center measurements C(X,Y,Z). The average of the Center measurements and the resulting North-to-Center (N→C(X,Y,Z)) and South-to-Center (S→C(X,Y,Z)) data was then computed:

$$\text{Average C(X,Y,Z)} = [C(X,Y,Z) + (N \rightarrow C(X,Y,Z)) + (S \rightarrow C(X,Y,Z))]/3$$

2. The North and South measurements were respectively transformed to the Center measurements, in the Tracker head system. The coordinates of the North and South Tracker heads were also computed with the Center Tracker head as (0, 0, 0). The polar coordinates were computed from the resulting North-to-Center (N→C(X,Y,Z)) and South-to-Center (S→C(X,Y,Z)) data. A network adjustment was performed using the polar coordinates of the Center measurements $C(r, \theta, \phi)$ and the computed polar coordinates from the resulting North-to-Center (N→C(r, θ , ϕ)) and South-to-Center (S→C(r, θ , ϕ)) data. The three Tracker head positions were treated as unknowns in the adjustment. The à priori standard errors used for weighting in the adjustment were $\sigma_r = 35$ microns for radial distances and $\sigma_\theta = \sigma_\phi = 1$ arcsecond for the angles.
3. Spatial distances computed from the measured (X,Y,Z) coordinates at each Tracker station were used in a trilateration network adjustment. The distance between the coordinates of two points is given as [3]:

$$d = [(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2]^{1/2}$$

or in polar coordinates as [3]:



$$d = \{r_1^2 + r_2^2 - 2r_1r_2 [\cos \phi_1 \cos \phi_2 + \sin \phi_1 \sin \phi_2 \cos(\theta_2 - \theta_1)]\}^{1/2}$$

The à priori standard error for the spatial distances used for weighting in the adjustment is computed by error propagation as follows [3]:

$$\sigma_d = [(\partial d / \partial r_1)^2 \sigma_{r_1}^2 + (\partial d / \partial r_2)^2 \sigma_{r_2}^2 + (\partial d / \partial \theta_1)^2 \sigma_{\theta_1}^2 + (\partial d / \partial \theta_2)^2 \sigma_{\theta_2}^2 + (\partial d / \partial \phi_1)^2 \sigma_{\phi_1}^2 + (\partial d / \partial \phi_2)^2 \sigma_{\phi_2}^2]^{1/2}$$

where the à priori standard error for radial distance $\sigma_{r_1} = \sigma_{r_2} = 35$ microns, the à priori standard error for horizontal angle $\sigma_{\theta_1} = \sigma_{\theta_2} = 1$ arcsecond, and the à priori standard error for vertical angle $\sigma_{\phi_1} = \sigma_{\phi_2} = 1$ arcsecond.

Comparisons of results from all the three methods yielded differences of ± 0.001 inch in the horizontal (X, Y) coordinates and ± 0.003 inch in the elevation (Z). These differences are within the measurement noise.

3.6 Analysis of Survey Results

3.6.1 Horizontal Coordinates

Table 1 shows the final results of the horizontal coordinates after the transformations for the Laser Tracker survey. The BETS survey results of 1992 and 2000 are also shown in the Table. Since there were no elevations measured directly to the old brass points, a direct comparison could not be made in elevation.

Table 1. Horizontal Coordinates from all Survey Campaigns

TRACKER - 2001			BETS - 2000			BETS - 1992		
Point	X	Y	Point	X	Y	Point	X	Y
	(in)	(in)		(in)	(in)		(in)	(in)
D-0003	-252.215	294.039	D-0003	-252.203	294.015	D-0003	-252.197	294.000
D-0011	23.785	294.047	D-0011	N/A	N/A	D-0011	23.792	293.994
D-0012	251.797	294.059	D-0012	N/A	N/A	D-0012	251.785	294.004
D-0013	251.799	-294.129	D-0013	N/A	N/A	D-0013	251.776	-294.075
D-0018	23.775	-294.122	D-0018	N/A	N/A	D-0018	23.783	-294.078
D-0021	-252.236	-294.131	D-0021	-252.214	-294.113	D-0021	-252.205	-294.080
D-0022	-36.745	-294.126	D-0022	-36.736	-294.104	D-0022	-36.738	-294.082
D-0023	-36.739	294.039	D-0023	-36.729	294.039	D-0023	-36.741	293.999
D-0024	-36.758	0.012	D-0024	-36.767	0.029	D-0024	-36.792	0.005



Table 2 shows the differences (dX, dY) in the horizontal coordinates between the BETS-1992, BETS-2000 and Tracker-2001 surveys. Figures 17 through 20 show the graphical representation of these differences. The differences between the BETS-1992 survey and the Tracker-2001 survey range from -0.034 to 0.031 inch in X and -0.055 to 0.054 inch in Y. The

Table 2. Horizontal Coordinate Differences between Survey Campaigns

DIFFERENCES			DIFFERENCES			DIFFERENCES		
BETS-1992 - BETS-2000			BETS-1992 - TRACKER-2001			BETS-2000 - TRACKER-2001		
Point	dX	dY	Point	dX	dY	Point	dX	dY
D-0003	0.005	-0.015	D-0003	0.018	-0.039	D-0003	0.013	-0.024
D-0011	N/A	N/A	D-0011	0.007	-0.053	D-0011	N/A	N/A
D-0012	N/A	N/A	D-0012	-0.012	-0.055	D-0012	N/A	N/A
D-0013	N/A	N/A	D-0013	-0.023	0.054	D-0013	N/A	N/A
D-0018	N/A	N/A	D-0018	0.008	0.044	D-0018	N/A	N/A
D-0021	0.009	0.033	D-0021	0.031	0.051	D-0021	0.022	0.018
D-0022	-0.002	0.022	D-0022	0.007	0.044	D-0022	0.008	0.022
D-0023	-0.012	-0.040	D-0023	-0.002	-0.040	D-0023	0.010	0.000
D-0024	-0.025	-0.024	D-0024	-0.034	-0.007	D-0024	-0.009	0.017

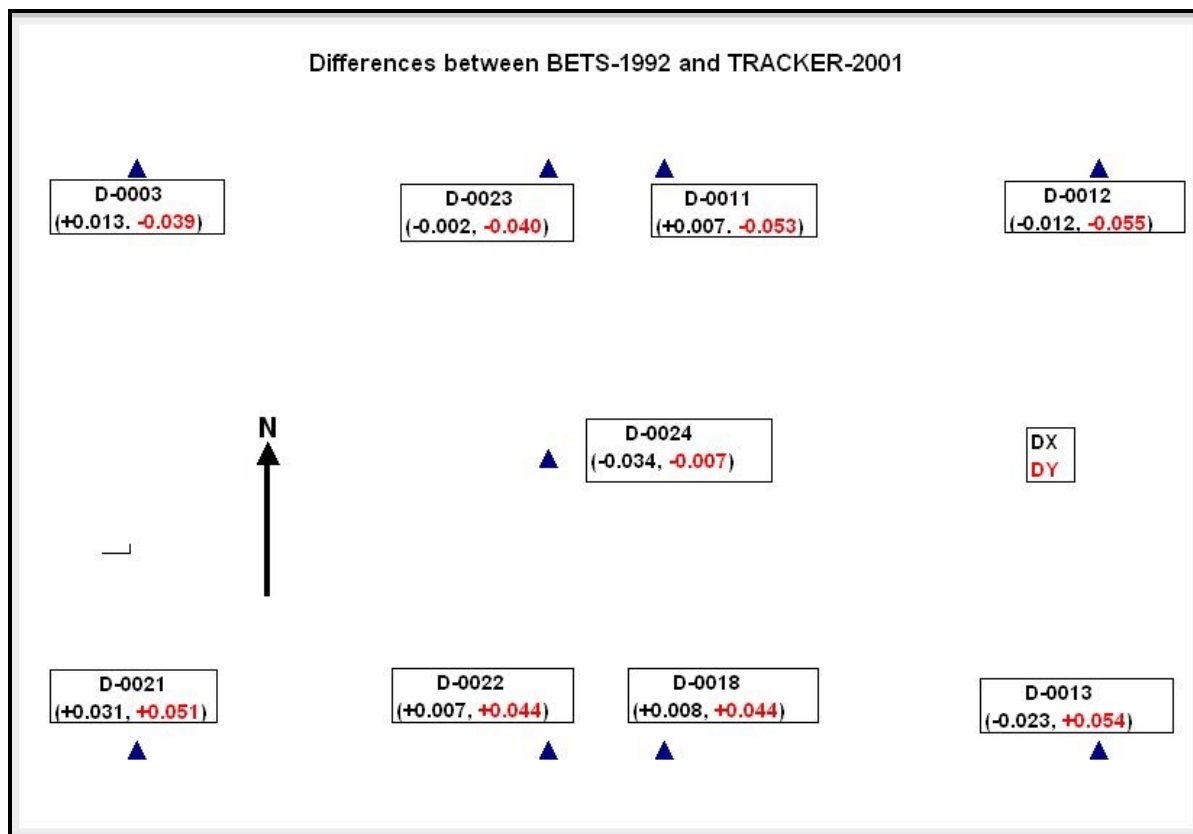


Figure 16. Differences between BETS-1992 and TRACKER-2001 (All Brass Points Used)

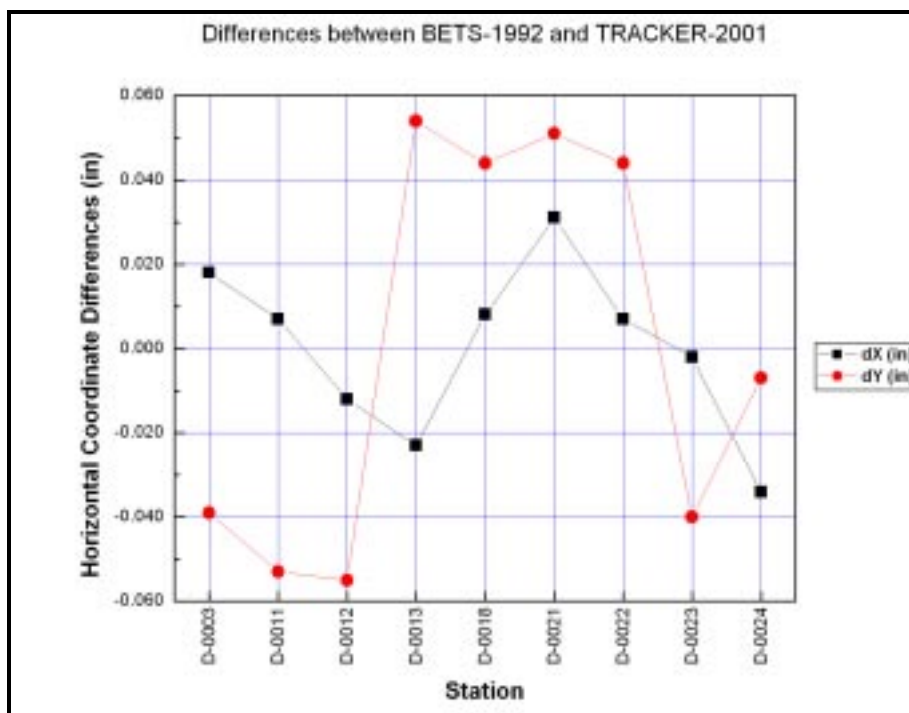


Figure 17. Differences between BETS-1992 and TRACKER-2001 (All Brass Points Used)

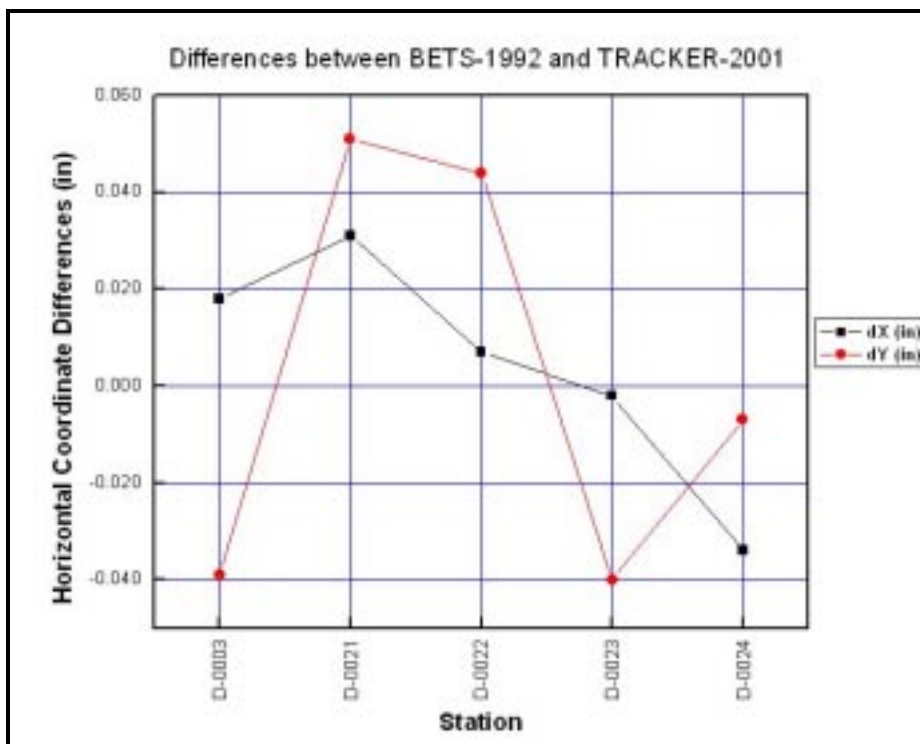


Figure 18. Differences between BETS-1992 and TRACKER-2001

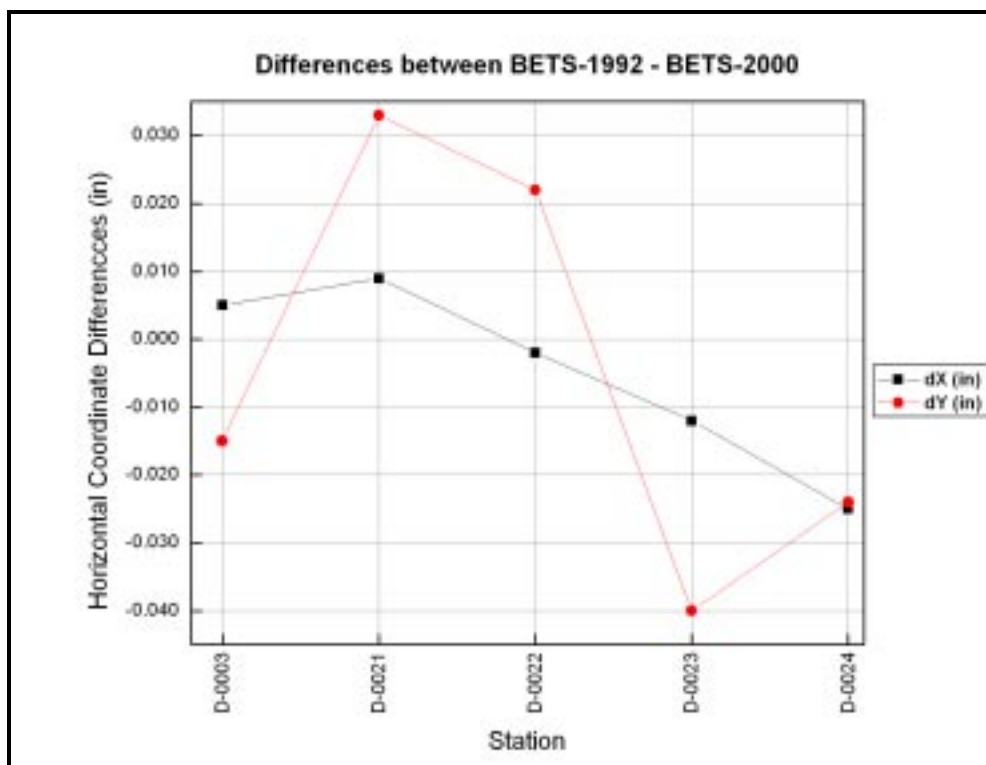


Figure 19. Differences between BETS-1992 and BETS-2000

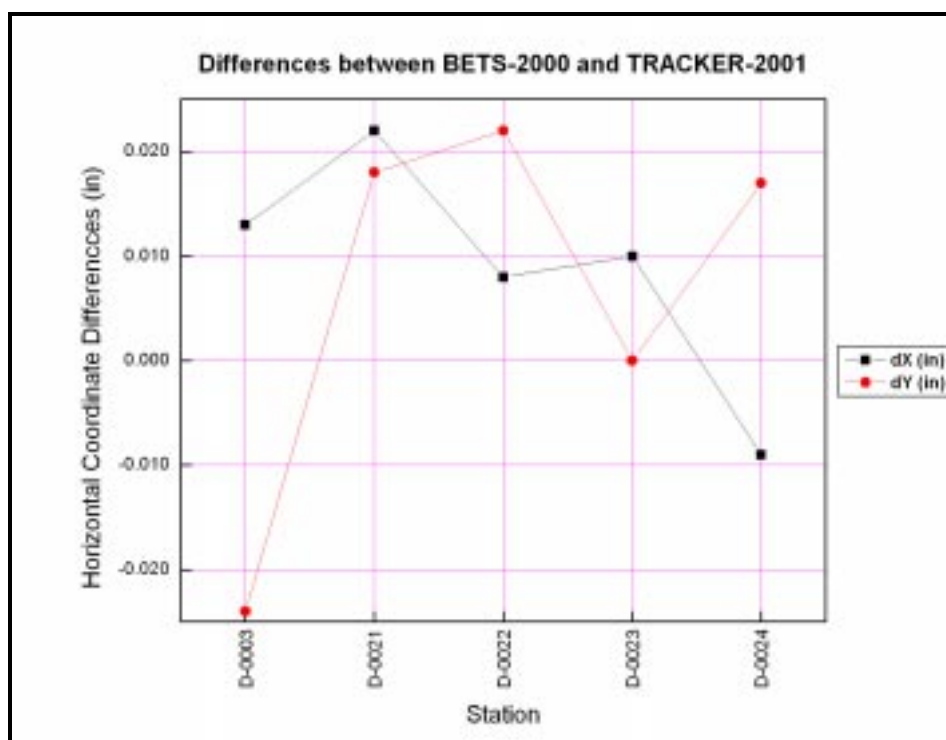


Figure 20. Differences between BETS-2000 and TRACKER-2001

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differences between the BETS-1992 survey and the BETS -2000 survey range from -0.025 to 0.009 inch in X and -0.040 to 0.033 inch in Y. The differences show that there is a systematic shift between the BETS-1992 survey and the Tracker-2001 survey (Figures 16 and 17). A lot of activities had taken place in the collision hall since the Run I experiment, including the removal and replacement of the 3000 ton shielding wall, and the 5500 ton detector. Comparisons yield similar systematic shift between the BETS-1992 survey and the BETS 2000 survey (Figure 18 through 20).

The differences between the BETS-2000 survey and the Tracker-2001 survey range from -0.009 to 0.022 inch in X and -0.024 to 0.022 inch in Y. This differences could be attributed to the fact that the Laser Tracker is a more accurate instrument with less human interaction during the data collection phase. Thus the 2001 Laser Tracker survey derived horizontal coordinates were adopted as the new coordinates of the nine brass control points.

3.6.2 Elevations

Table 3 shows the history of the measured elevations in the D0 collision hall. The elevations from the elevation run of January 24, 2001 were those used in the network adjustment and transformations. The measured elevations take precedence over any other computed or derived elevation. Table 3 also shows the elevations of all the tie-rods and the floor and sidewalk points measured before and after roll-in. The elevation differences before and after roll-in are shown in Table 4.

The results show that the collision hall sank after the D0 detector was rolled into the hall. The largest deformation is at the east end of the hall close to the shielding block wall (Figure 21). Figure 22 shows the deformation from the continuous elevation measurements of February 2001 and May 2001 after roll-in. These results reveal further sinking of the hall but not by much after taking into account the measurement noise.

3.7 Measurements After Roll-in

After the detector was rolled into the collision hall and the shield block wall was rebuilt on the east side of the hall, new tie-rods were installed on the east wall for elevation ties. The centerbeam was surveyed relative to the new control points and tie-rods, and the elevation of the tie-rods measured relative to the low beta quads. Due to the large weight of the detector continuous elevation runs must be performed for monitoring elevation deformation. Since time and space were very limited in the collision hall to survey these new positions of the components, distance measurements with stick-mics, and the V-Stars system were used to make the measurements for the horizontal coordinates.



Table 3. Elevation History in the D0 Collision Hall

ELEVATION HISTORY IN THE DO COLLISION HALL						
						Compiled by: O'Sheg Oshinowo
						Date :- May 31, 2001
NOTE						
16-Nov-00	Collision Hall Empty					
24-Jan-01	North and South EMC Trusses already situated on the Sidewalks; Pit empty					
31-Jan-01	- After Detector roll-in					
21-Feb-01	- After Detector roll-in					
	ACTUAL ELEVATION = Elevation (in) + 8640.0 in (720 FT)					
21-May-01	- After Detector roll-in					
STA	Elevation (in)	Elevation (in)	Elevation (in)	Elevation (in)	Elevation (in)	Comments
	16-Nov-00	24-Jan-01	31-Jan-01	21-Feb-01	21-May-01	
	BK 95-10, P. 77	Level Run	BK 95-10, P. 102	Level Run	Level Run	Vertical Drop
D0C15W	-108.698	-108.698	-108.698	-108.706	-108.706	Tie Rod - TOP
D-0047		-150.050		-150.066	-150.070	Dead Bolt - South Side Walk
D-0038	-149.846			-149.858	-149.855	Dead Bolt - South Side Walk
D-0037	-150.136		-150.133	-150.151	-150.152	Dead Bolt - South Side Walk
D-0036	-149.884	-149.861		-149.881	-149.891	Dead Bolt - South Side Walk
D0C10SW		-163.318		-163.338	-163.335	Tie Rod - BOT
D-0035	-239.823			-239.860	-239.853	Pit Floor - West
D-0034	-239.951			-239.985	-239.977	Pit Floor - West
D0C10NW	-161.554	-161.550		-161.581	-161.571	Tie Rod - BOT
D0C15UW	-108.063	-108.063		-108.087	-108.070	Tie Rod - TOP
D-0041		-149.927		-149.975	-149.961	Dead Bolt - North Side Walk
D-0031	-149.752			-149.769	-149.754	Dead Bolt - North Side Walk
D-0032	-150.037			-150.072	-150.060	Dead Bolt - North Side Walk
D-0033	-150.131	-150.100	-150.105	-150.151	-150.138	Dead Bolt - North Side Walk
D-0040		-239.902		-239.986	-239.977	Pit Floor - East
D-0039		-240.009		-240.083	-240.068	Pit Floor - East

After the D0 detector was closed for the start of Run II, the magnet-on east-west position of the CF's was measured for the new centerbeam position by measuring stick-mic distances to the new control points and tooling balls on the west wall. The V-Stars system was used to measure new centerbeam position using the new control points on the north and south pit walls. Stick-mic distances were also measured between points on the EMC trusses and the north and south walls of the collision hall. These measurements would be repeated continuously at any opportune time during the shutdown periods (short periods of interrupted Tevatron operation).



Table 4. Elevation Differences Before and After Roll-in

DIFFERENCES			
BEFORE ROLL-IN - AFTER ROLL-IN			
(24-Jan-2001 - 21-Feb-2001)			
Point	X	Y	DZ
	in	in	in
D-0033	245.547	308.006	-0.051
D-0036	222.756	-309.594	-0.020
D-0039	272.594	85.295	-0.074
D-0040	272.910	-73.526	-0.084
D-0041	-164.006	293.238	-0.048
D-0047	-164.469	-292.842	-0.015
D0C10SW	-272.853	-268.726	-0.020
D0C10NW	-218.788	268.376	-0.031
D0C15UW	-286.579	150.508	-0.024
D0C15W	-285.929	-151.434	-0.008

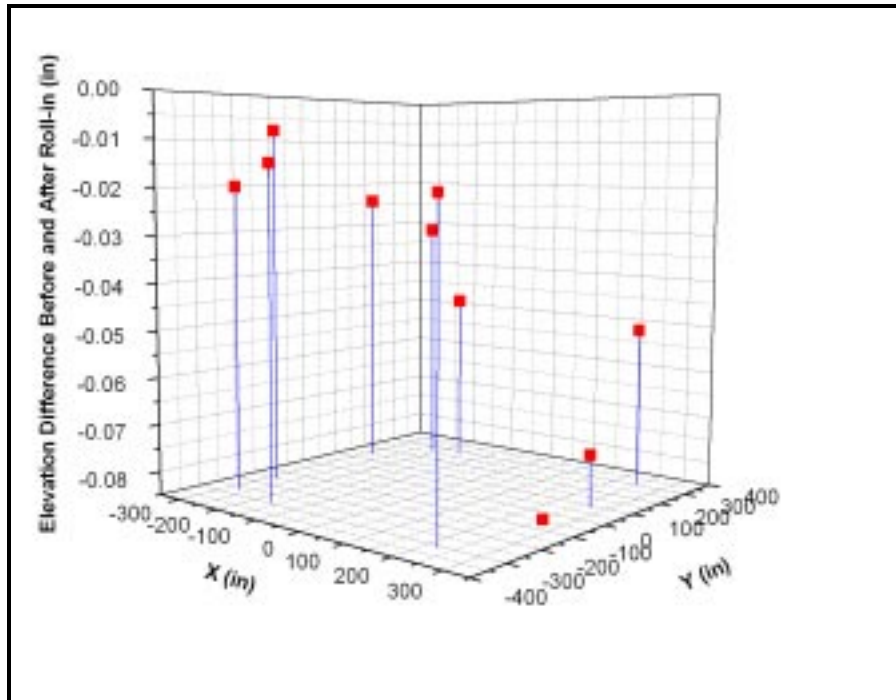


Figure 21. Elevation Differences Before and After Roll-in

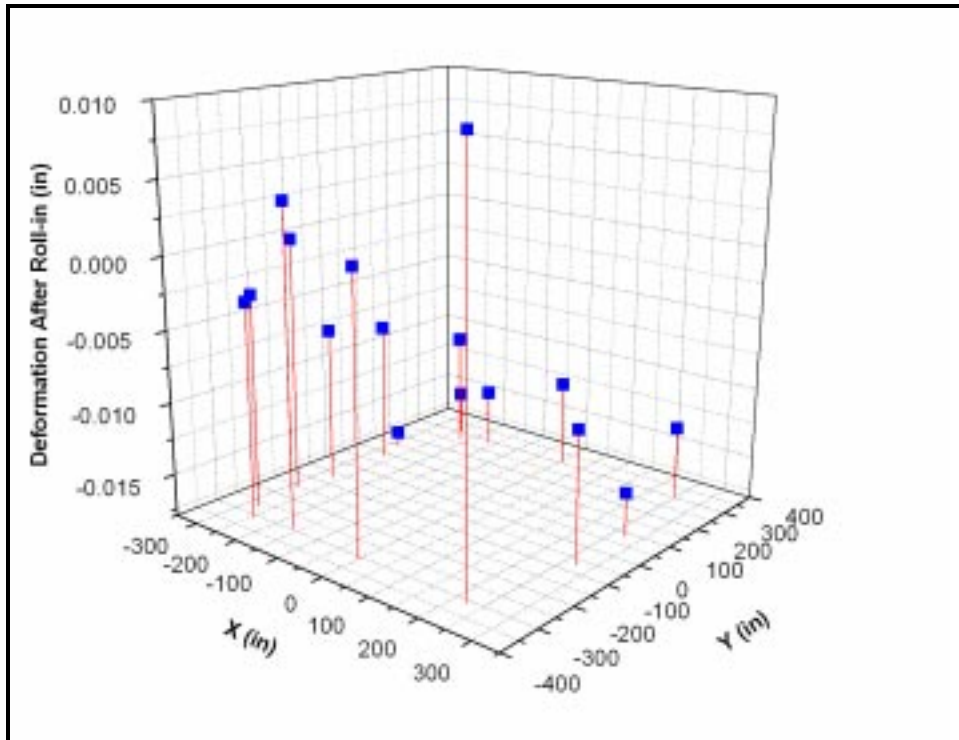


Figure 22. Deformation After Roll-in

4. CONCLUSIONS

The D0 detector had been upgraded for the Tevatron Run II. The detector was assembled in the Assembly Hall and was rolled into the Collision Hall in January 2001. Prior to moving the detector to the Collision Hall, the existing survey monuments were densified with new monuments. These monuments were surveyed and tied to the old 1992 brass coordinates in the Tevatron D0 global coordinate system. Three different surveying methods were used for the survey - the Laser Tracker, the BETS, V-Stars, and other optical systems. The survey revealed a systematic shift in the horizontal coordinates and an elevation deformation between the old 1992 survey and the new 2001 survey.

The initial phase III survey of the detector, which is the survey of the detector relative to the collision hall, was also completed. The Phase III survey will be repeated as required during the upcoming shutdowns. The upgrade of the D0 detector was fully commissioned on March 1, 2001, and thus marked the official start of the Run II experiment.



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